3.7 Optical fiber pressure sensing principle

Objective: Understand the principle of optical fiber pressure sensing and conduct fiber pressure sensing experiment

Equipment list

LLL-2 He-Ne laser	1
633 nm Single-mode fiber (FC/PC at one end)	1
Fiber interference demonstrator	1
Fiber scribe	1
Fiber stripper	1

Theory

Pressure sensing principle based on optical fiber M-Z interferometer

The fiber pressure sensor used in this experiment is based on dual-beam interference. According to dual-beam interference theory, the interference intensity is expressed as

$$I \propto 1 + \cos\delta \tag{7-1}$$

where δ is the phase difference corresponding to the optical path difference between the two arms of an interferometer. The interference intensity reaches its maximum when δ is equal to the integral multiple of 2π. Pressure changes the optical path of one arm of interferometer and as a result, it changes the optical path, or phase, between the two arms of the interferometer. The phase change is reflected by the change of light intensity according to formula (7-1).

Experiment

1) Referring to Figure 18, prepare the 1 m optical fiber and then couple the laser into one end of the fiber through the collimating lens. The FC/PC end should be placed in the fiber clamp facing the white screen until optimum coupling is achieved. **Note:** The power indicator can be used to monitor the power output of the fiber.
2) Connect the FC/PC end of the single-mode fiber to the interferometer through the FC/PC connector labelled as "Fiber Optic Input". The interference pattern should be observed on the ground glass screen as shown in Figure 13. **Note**: ambient light may need to be turned off before observing the interference pattern.
3) Fix the relative position and adjust the pressure controller to analyse the interference pattern.

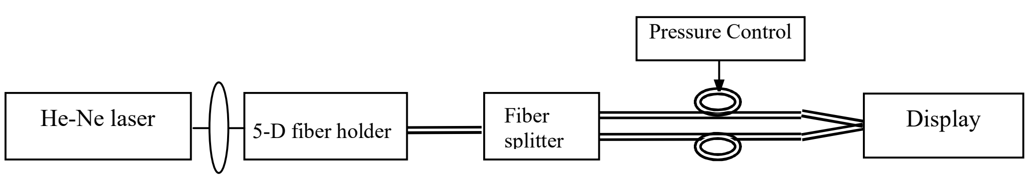

Figure 18 Schematic of fiber pressure sensing

Pressure measurement is recognized through the interferometer that has one arm as the reference arm and the other as sensing arm, together with a display unit. This experiment is based on the qualitative interference observation for the change of interference fringes as caused by pressure.

Note: The length of optical fiber for pressure sensing is 60 mm. **Warning**: Avoid applying excessive pressure to the fiber, as otherwise the bare fiber could break.

3.8 Optical fiber beam splitting

Objective: Learn the applications and characteristics of optical fiber beam splitter and measure the parameters of optical fiber beam splitter

Equipment list

1310 nm/1550 nm Handheld laser source	1
1310 nm or 1550 nm Single-mode fiber splitter	1
Handheld optical power meter	1

Theory

Optical fiber beam splitter and its applications

Optical fiber beam splitter is a passive component used for light splitting, combining, inserting, and distributing. In an optical communication system, fiber beam splitter is used for splitting the input of an optical signal from data trunk and data circuits, and it is also used for the acquisition of a reference optical signal from the light path to find out the characteristics and status of light emitting out of components and transmission line. At present, optical fiber beam splitters have become an indispensable device in optical fiber network, local area network and CATV network.

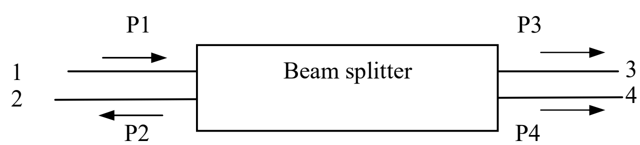

Figure 19 Schematic of fiber beam splitter

There are a variety of optical fiber beam splitters that can be made by partly heating up 2 or more (up to 100) optical fibers and then fusing them together.

The main parameters

The main parameters are splitting ratio, insertion loss, and isolation.

A. Splitting ratio

It is the ratio of optical powers between output ports. For example, if the ratio of light powers between output port 3 and output port 4 in Figure 19 is: $P_3/P_4=3/7$, which means the beam splitting ratio is 3:7. For a general 3-dB splitter, the ratio of light powers between two output ports is 1:1. For a direction coupler with two output ports, the beam splitting ratio varies from 1:1 to 1:99.

B. Insertion loss

Insertion loss is the loss magnitude of a beam splitter. It is expressed by the logarithm of the ratio between the sum of light power from all output ports and input light power. The unit is dB. For example, the loss is expressed by α, if P_1 is input light power to port 1, P_3 and P_4 are output light powers from port 3 and port 4, respectively, then, we get

$$\alpha = -10 \times \log\left(\frac{P_3 + P_4}{P_1}\right)(dB) \tag{8-1}$$

Generally, $\alpha \leq 0.5$ dB is preferred.

C. Isolation

In Figure 19, input light power P_1 to port 1 should all come out of port 3 and port 4. Theoretically, there is no light output of port 2. However, in fact, there is a little bit output light power P_2 from port 2. The magnitude of P_2 indicates the isolation between port 1 and port 2. If A_{1-2} represents the isolation between port 1 and port 2, then

$$A_{1-2} = -10 \times \log\frac{P_2}{P_1}(dB) \tag{8-2}$$

Experiment

Refer to Figure 20 and measure the performances of a beam splitter.

1) Connect the hand-held light source with the fiber splitter.
2) Measure the light powers of the output ports
3) Determine the splitting ratio and calculate the 'insertion loss' and 'isolation'.

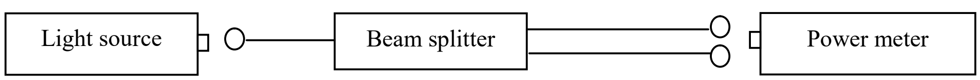

Figure 20 Schematic of beam splitter measurement

Figure 21 Photo of experimental setup for splitter measurement